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# HEAT-TRANSFER TESTS OF TWO STEEL CYLINDER BARRELS WITH ALUMINUM FINS MANUFACTURED BY FACTORY PRODUCTION METHOD

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WASHINGTON

MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

# HEAT-TRANSFER TESTS OF TWO STEEL CYLINDER BARRELS WITH ALUMINUM FINS MANUFACTURED BY FACTORY PRODUCTION METHOD

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## INTRODUCTION

At the request of the Bureau of Aeronautics, Navy Department, an engine cylinder barrel with aluminum fins was tested (reference 1). The tests showed that the thermal bond between the fins and the aluminum base was very good and that the bond between the aluminum base and the steel barrel was satisfactory. The tests further showed that the mechanical bonds between the cylinder parts would probably be satisfactory.

The present report presents the results of tests made on two more engine cylinder barrels with aluminum fins. The method of attaching the fins to the steel for these barrels is similar to that of the barrel described in reference 1. The two barrels, the results for which are to be presented herein, were manufactured by a method to be used in the factory production of large numbers of engine barrels. The purpose of the tests was to determine the heat-transfer coefficients and the excellence of the bonds between the aluminum fins and the aluminum base and between the aluminum base and the steel of the two barrels when manufactured by a large-volume production method. The tests were made at the request of the Bureau of Aeronautics, Navy Department.

## APPARATUS AND METHODS

The apparatus and methods used to test the two barrels were similar to those used to test the barrel described in reference 1. The fin spacing and thickness were the same on the two barrels reported herein as for the barrel tested in reference 1, but the fin width was 0.438 inch or 1/16 inch greater than that for the first barrel. One of the barrels is shown in figure 1. Thermocouples were attached to the steel barrel by the method C of reference 1, using two plugs for each thermocouple.

## RESULTS AND DISCUSSION

### Heat-Transfer Tests

The experimental over-all heat-transfer coefficients of the two barrels based on the temperature difference between the steel and the cooling air and the temperature difference between the aluminum base and the cooling air are shown in figure 2. One barrel shows about a 5 percent better heat transfer than the other barrel. No difference in the coefficients could be observed when either the temperature of the steel or the temperature of the aluminum base was used for either barrel. This indicates that the bond between the steel and the aluminum base of both barrels is very good. The curves for both barrels were approximately 17 percent higher than the calculated curve for aluminum fins cast integrally. This difference is greater than that usually obtained between experimental and calculated results. The tests of one barrel were, therefore, repeated and the same result obtained. For very short fins, very wide fins, or fins close together it has been observed that the checking of experimental results with calculated results is more difficult than with fins of normal proportions. The comparison of the experimental results with the calculated results of figure 2 serves the purpose of indicating that the bond between the fins and the aluminum base is very good.

Figure 3 shows the results of the tests on the barrel reported in reference 1. This barrel had a fin width of 3/8 inch, and comparison of the experimental heat-transfer coefficients of figure 3 with those of the two barrels of figure 2 shows that adding 1/16 inch to the fin width increased the coefficients of the two barrels approximately 20 percent. Any addition of width to short fins improves the heat transfer appreciably. The difference between the calculated coefficients for the 0.438-inch and 0.375-inch fin widths is approximately 15 percent.

Calculations have been made of the gain to be expected in heat transfer and the decrease in fin weight by using aluminum instead of steel fins of the proportions of the fins on the two barrels reported herein. The increase in heat transfer is approximately 16 percent, and the decrease in fin weight 41 percent. As noted in reference 1, an appreciable increase in heat transfer can be obtained with the pressure differences available for cooling in flight by using a wider space between the fins than 0.052 inch. Thus, changing the fin space of the present barrels from 0.052 to 0.09 inch at a pressure difference of 4 inches of water will increase the heat transfer about 16 percent and decrease the fin weight approximately 20 percent.

## Physical Tests

One barrel was cut in half and one half was cut in quarters in order to determine how good the bonds between the steel and the aluminum base and between the fins and the aluminum base were mechanically. One edge of one of the quarters was polished and etched, and the result shown in figure 4. The outline of the fins in the aluminum base shows up about the same as for the barrel tested in reference 1. The mechanical bond between the fins and the aluminum base was considered satisfactory in the case of the barrel of reference 1, so that it can be concluded that such will be the case for the barrels reported herein.

The steel was then pried loose from the aluminum of the quarter of the barrel that was not etched. In the past, a half of a barrel has been used for this particular test. The quarter section was used in the present test because the half section is to be used in tests to develop an apparatus to determine quickly the thermal bond between the steel and aluminum of a large number of these barrels. The force required to remove the steel from the aluminum of the quarter section was much less than for the half sections previously used (reference 1), but it is thought that for a complete barrel with the strengthening provided by the fins no trouble should be experienced mechanically.

## CONCLUSIONS

1. Heat-transfer tests indicate that the thermal bonds between the aluminum fins and the aluminum base and between the aluminum base and the steel for the two barrels tested are very good.

2. The etching tests indicate that the mechanical bond between the fins and the aluminum base for the two barrels is about the same as for the barrel tested in reference 1, which was considered satisfactory.

3. The mechanical bond between the steel and aluminum base should be satisfactory in a complete barrel.

4. The tests indicate that the method of manufacture to be used in large-volume production of these barrels should be satisfactory.

5. The addition of 1/16-inch width to aluminum fins 3/8 inch wide increased the heat-transfer coefficient of the test cylinders 20 percent.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 12, 1940.

REFERENCE

1. Ellerbrock, Herman H., Jr.: Heat-Transfer Tests of a Steel Cylinder Barrel with Aluminum Fins with Improved Bonding between Steel Barrel and Aluminum Base. NACA Memo. rep., July 17, 1940.

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Figure 1. - Cylinder barrel.

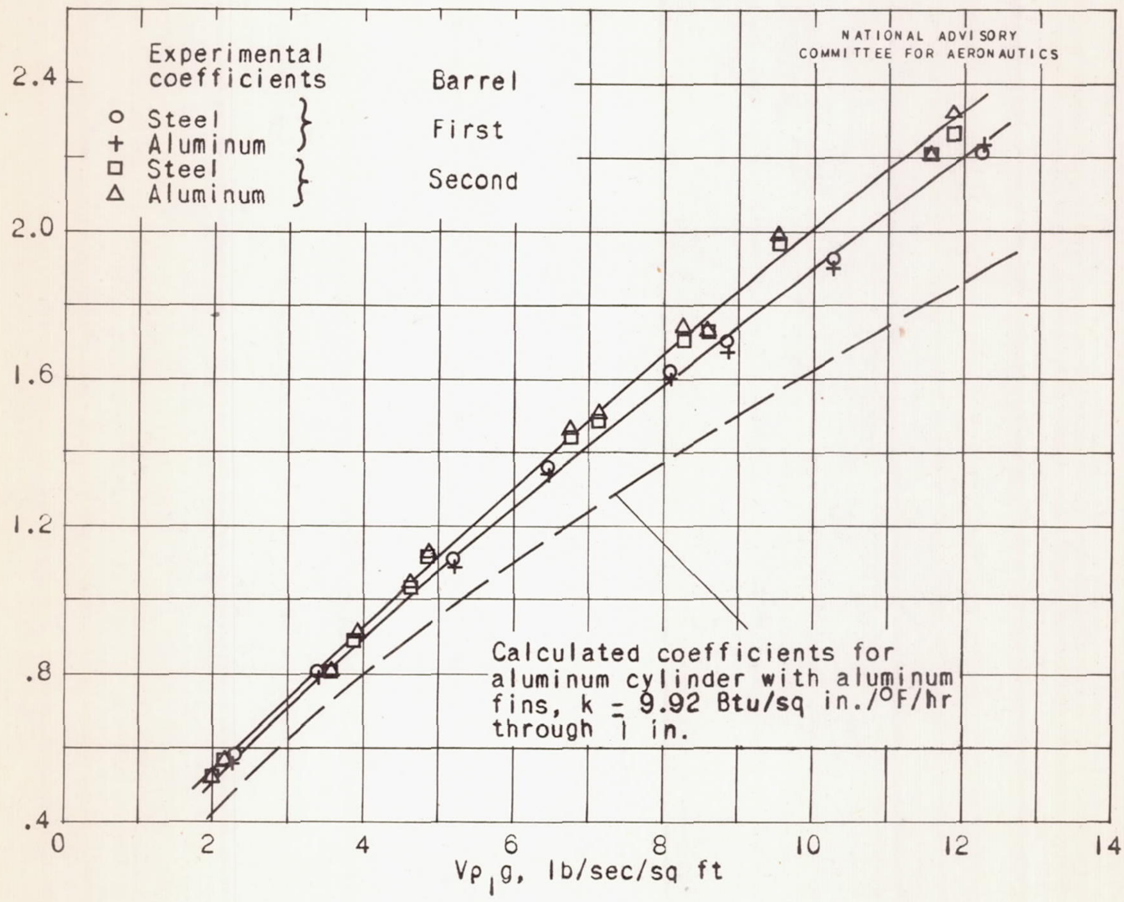


Figure 2. - Comparison of over-all heat-transfer coefficients of test cylinder with calculated coefficients. Fin width, 0.438; fin thickness, 0.025; fin space, 0.052.

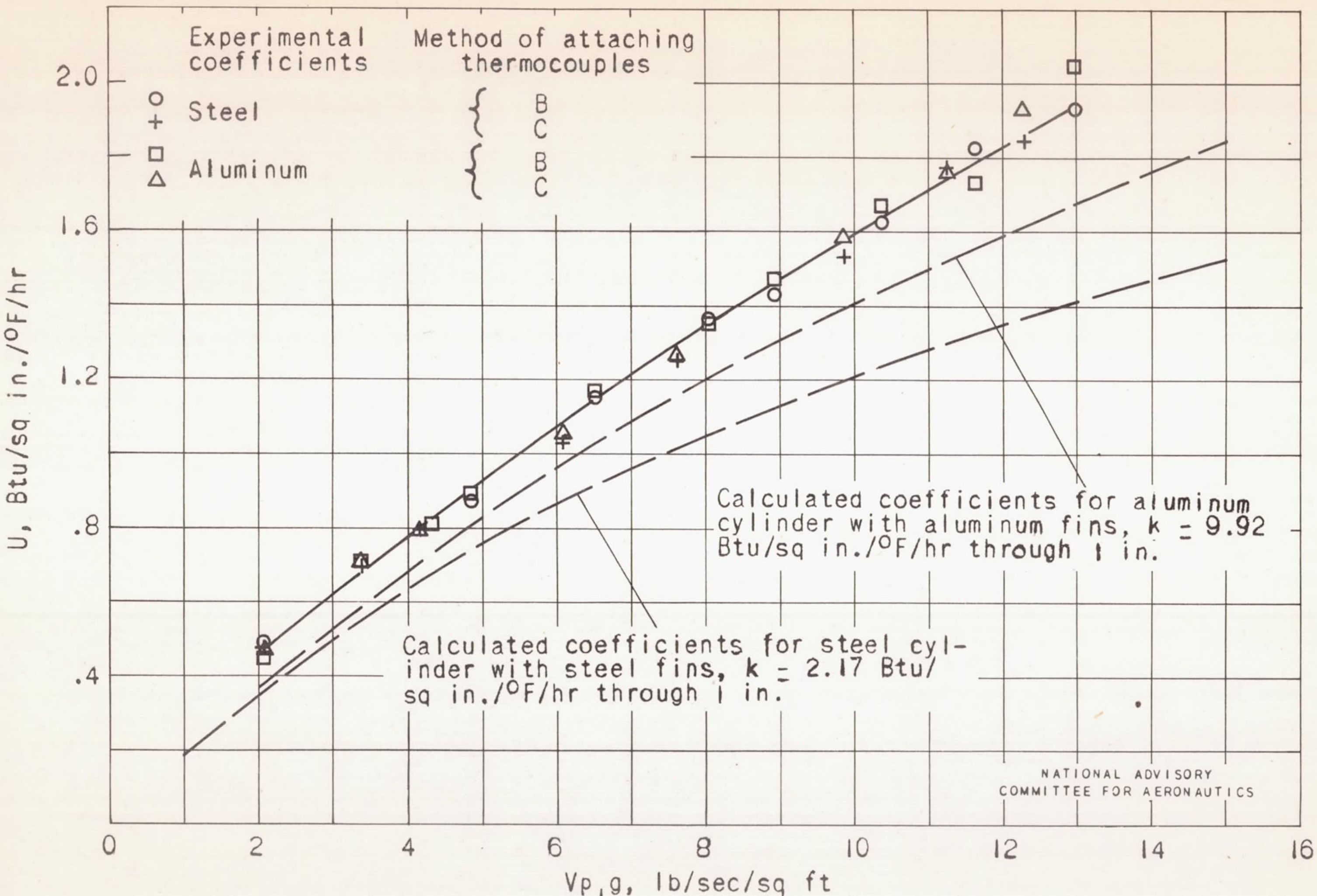


Figure 3. - Comparison of over-all heat-transfer coefficients of test cylinder with calculated coefficients. Fin width, 0.375; fin thickness, 0.025; fin space, 0.052.

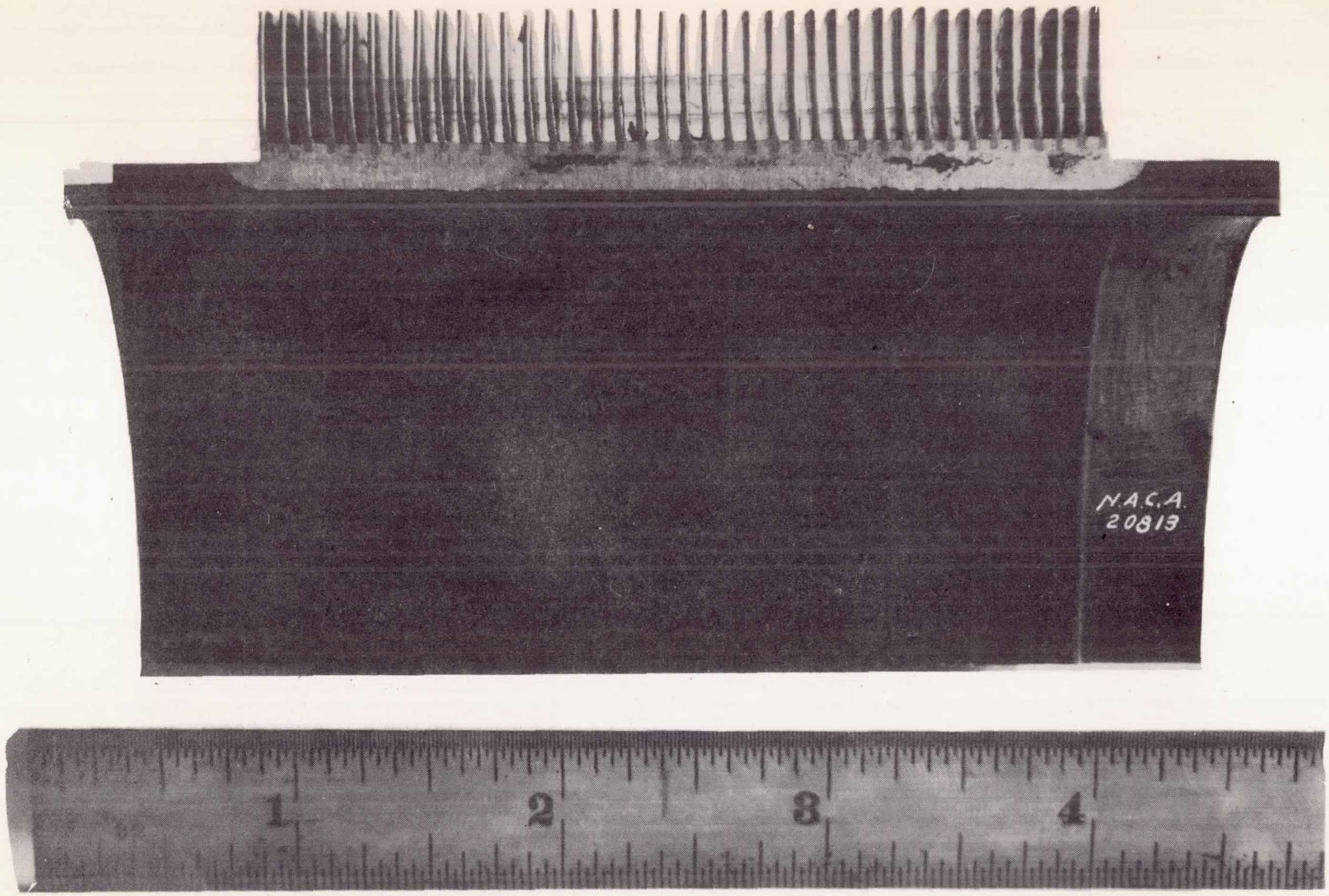


Figure 4. - Polished and etched section of cylinder showing fin outline.